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Impacts of climate change and its mitigation in the Barents region

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Abstract: The global temperature has increased over 1 degree since the pre-industrial period. Within the Barents Region, the increase has been ca. 2 degrees, and warming is expected to continue over the next century. Based on energy system analysis with the TIMES-VTT model on the one hand, and a literature review on the other, this study identifies how different economic sectors in the Barents Region are affected by changes in climate, and by the climate change mitigation and adaptation actions in the region. According to the results, the Barents region is likely to be strongly affected by the impacts of climate change despite high spatial variation in the impacts across the Barents region. Changing climate will have severe impacts especially on the more vulnerable sectors, societies, and local environments that have less possibility for adaptation. Political action is needed on national, regional, and municipal levels, but these levels should work together and complement each other. As adaptation is unavoidably required, it is important to highlight and suggest priority areas to national adaptation plans from the Barents region's perspective. Moreover, collection and utilization of local knowledge in adaptation is crucial.

ABOUT THE AUTHOR

Dr. Laura Sokka holds a Ph.D. in environmental science and policy from the University of Helsinki. Sokka works as a Senior Scientist in the VTT Technical Research Centre of Finland Ltd. She is an expert in life cycle assessment and environmental impact assessment of products and systems. Her recent work has primarily concerned environmental impacts of different renewable energy technologies, renewable energy technologies in the Arctic and the sustainability of circular economy and local energy systems. She was one of the Research Scholars in the first Fulbright Arctic Initiative Program in 2015-2016 where she studied the use of forest bioenergy in the Finnish Arctic and the advancement of renewable energy technologies in the Arctic Region. This paper is partly based on a project in which it was studied how climate change and the mitigation actions needed for implementing the Paris Agreement affect the economic activities in the Barents region by 2050. It also reflects her wider research interests on climate change impacts in the Arctic.

PUBLIC INTEREST STATEMENT

This paper studies how different economic sectors in the Barents Region are affected by changes in climate, and by the climate change mitigation and adaptation actions in the region during the next decades. The results show that the impacts of climate change are manifold, ranging from positive to negative, and being different from one economic sector to another. The positive impacts include, e.g., increased energy security, and the potential agricultural benefits from higher yields and growing of new crop species in areas that were previously too cold for them. There are also many possible negative impacts, e.g. the economic costs and risks due to potential damage from ice and flooding, increased occurrence of plant diseases due to warmer temperatures and higher prevalence of snow and storm damages on forests. Impacts will be especially severe on the more vulnerable sectors, societies, and local environments that have less possibility for adaptation.

Subjects: Environmental Sciences; Climate Change; Environmental Impact Assessment; Environmental Issues; Environment & Resources; Environment & Society; Environmental Change & Pollution

Keywords: Barents; climate change mitigation; climate impacts; review; energy system modelling; economic sectors

1. Introduction

The global average temperature has increased by ca. 1.2 degrees since the pre-industrial period (Masson-Delmotte et al., 2018). Even if the Paris Agreement is successful in its aims, considerable environmental changes are still likely to take place, requiring adaptation (Schleussner et al., 2018). Warming has been stronger in the Arctic region (Arctic Monitoring and Assessment Programme, 2017; Overland et al. 2014) and this trend is expected to continue in the future (Benestad et al., 2016). In addition to warming the atmosphere, climate change impacts several other processes, such as precipitation, snow cover, storms and other severe weather events, ice and thawing of the permafrost. As warming affects several key features of the Arctic environment, the Arctic is particularly sensitive to temperature increase. The Barents Region covers the northern parts of Norway, Sweden, Finland, and the north-western part of Russia. The region was defined in 1993 as an area of political cooperation between these countries. The Barents region thus forms an area with established political and economic cooperation, which is coordinated by the Barents Euro-Arctic Council (BEAC).[1] The aim of this paper is to assess how the impacts of climate change, and climate change mitigation and adaptation activities are likely to affect the Barents region and its economy. The study consists of 1) an analysis of two possible mitigation pathways of the Barents, and 2) a literature review of the climate impacts. The temporal scope of the analysis extends to the year 2050. The impacts of climate change interact with other factors (e.g., acidification and impact of fisheries). Moreover, there are interacting social and economic drivers that affect the Barents area, such as population development, economic growth, growing demand for natural resources and land use issues and it is, therefore, difficult to predict the exact ecosystem impacts of climate change (Arctic Monitoring and Assessment Programme, 2017; Larsen et al., 2014). While acknowledging these uncertainties, in order to form a complete picture of the impacts of climate change and mitigation actions, it is important to construct an overview of them on the basis of available literature and modelling. This information can help communities, businesses and individuals to consider what climate risks they or their descendants might face in the future, and what are the best ways to adapt to possible changes.

2. Material and methods

2.1. Barents region

The Barents Sea is part of the Arctic Ocean, North of the shores of Northern Norway to the Northwest Russia. The Barents region is the land-area in proximity of the Barents Sea reaching from Nordland in Norway to Nenets and Komi in Russia (Figure 1).

A total of 5.1 million people lived in the Barents region in 2016, of which the majority resided in the Russian Barents. Oil and gas industries are very important for both Norwegian and Russian Barents. Norwegian Barents produces annually 15 Mtoe of oil and gas, which is 6% of the national total. Russian Barents production increased rapidly after 2001, when available data starts and reached a peak of 35 Mtoe in 2009. (ENTSO-E, 2017; PatchworkBarents, 2018)

The mining sector is vital to the Barents region, especially in Sweden and Russia, where the mining sector corresponds to 20% and 25% of regional Gross Value Added (GVA), respectively. Mined minerals include iron, gold, copper, silver, zinc, and many other basic metals and metals for industry use. Also coal is mined in the Komi region in Russia.

Figure 1. The Barents region.

The Nordic Barents region has 8% of the population in these countries, but it produces 20% of the electricity generated on Barents regions on an average year. The Nordic Barents regions have energy-intensive industry and average per capita electricity consumption is 60% above national averages. Sweden and Norway are important hydro-power producers and for the Swedish and Norwegian Barents regions, hydropower generation and export is a major income source. Finnish Barents region is a net electricity exporter when annual precipitation is above average and a net importer when it rains less. (ENTSO-E, 2017; Nordpool, 2018).

Agriculture and aquaculture are statistically small sectors in the region but are all important contributors to the local culture, employment, and economies (OECD, 2018; Statistics Finland, 2018; Statistics Norway, 2017; Statistics Russia, n.d.). In addition, part of the off-shore fishing activities are not accounted in the regional statistics. Particularly for indigenous communities, fishing, subsistence hunting and even small-scale farming are in many cases important contributors to households' nutrition, even though they are not the primary source of income for these populations.

Tourism is also an important economic activity in the Barents region, but its impact is divided under many other sectors, such as hotels, restaurants, transport, commercial, etc. It has been estimated that the direct economic impacts of tourism are between 1.5% and 3% in the Barents region countries, while their indirect impact could be up to 10% of GDP (Glomsrød & Aslaksen, 2009).

2.2. Modelling of mitigation pathways

The mitigation contributions by the Barents region countries up to 2050 were modelled with TIMES-VTT, a global integrated assessment model with high detail on energy production, transformation and end-use (Loulou et al. 2016; Ekholm et al., 2017). The analysis of climate change impacts is based on a review of existing literature.

The TIMES-VTT model is a partial equilibrium model of the global energy system based on linear optimization. As a bottom-up model of the energy system, it includes a detailed description of energy resources and a large database of energy technologies. Assuming efficient markets and perfect foresight, the model calculates a market equilibrium solution through cost minimization for energy production, transformation and end use under the given energy demand projections, technology assumptions and policies (e.g., targets for emission levels or global temperature increase).

The TIMES-VTT model is used to calculate long-term scenarios of global energy supply and use, as well as energy and non-energy-related greenhouse gas emissions and related mitigation options. Given projections on future energy, industrial, and transportation demand; development of energy technologies, available resources and policies governing energy use and emissions, the model finds the least-cost way of satisfying both the future energy demand and stated policy targets, e.g., emission limits. The model includes descriptions of national policies that steer the development in all energy sectors, including energy taxation, national targets for 2030, and specific sectoral targets in all energy sectors. Using an assumption for efficient energy and emission markets, the solution can be interpreted to simulate the ideal responses of individuals, companies, and governments to the specified policies. For example, an increase of a fuel tax can lead to fuel-switching, if cheaper substitutes are available, and a national emission target leads to cost-efficient emission reductions to meet the specified target, as would ideally occur under an economy-wide cap-and-trade system.

The main aim of the mitigation scenarios is to assess how the Barents region could contribute to the mitigation efforts of the Paris Agreement (see also Ekholm et al. (2017)). The model's geographical detail does not allow producing energy or emission scenarios for the Barents region itself but as the Barents region will be steered by national-level policies and market developments, modelling of the Barents countries as a whole has been considered relevant. It can be argued that the national-level energy and emission pathways presented here do provide an outlook for development also in the Barents region.

Given that the ultimate effectiveness of the Paris Agreement is not fully known, we portray two levels of global mitigation ambition, which are tied to the Representative Concentration Pathways (RCPs) used, e.g., in the IPCC AR5 report (Van Vuuren et al., 2011): either ambitious emission reductions are implemented globally, keeping the temperature increase well below 2°C (RCP2.6); or that developing countries' actions are more moderate, leading to a long-term temperature average increase of 2.4°C (RCP4.5). The RCP4.5 scenario would mean an average warming of 4–5°C in the Barents area (Arctic Monitoring and Assessment Programme, 2017).

2.3. Literature review on the environmental and economic impacts of climate change and climate change mitigation on the Barents region

An extensive and systematic literature review was conducted in order to study the predicted impacts of climate change on different economic sectors in the Barents region, and the impacts of climate change mitigation and adaptation within these sectors. The Google Scholar and Scopus databases were used as data sources. In addition, reference lists of the studies found were used. Searches were conducted using combinations of keywords in order to identify all available papers (Table 1). Titles and abstracts were studied in order to decide whether the source was relevant for the purposes of this paper. Papers published over 10 years ago (before 2009) were excluded from the review.

The snowballing technique was applied to reveal further relevant studies (e.g., Geissdoerfer et al., 2017). In this, two different methods were applied: First, the reference sections of the articles that had already been selected for the review were studied in order to spot further relevant papers (*backward snow-balling*). Then, the Google Scholar and Scopus databases were used to identify tracking databases to identify papers that had cited the papers included in the review (*forward snow-balling*). Finally, in total 36 papers were included in the comprehensive review Figure 2. List of the literature selected for the review is presented in Appendix 1.

3. Results and discussion

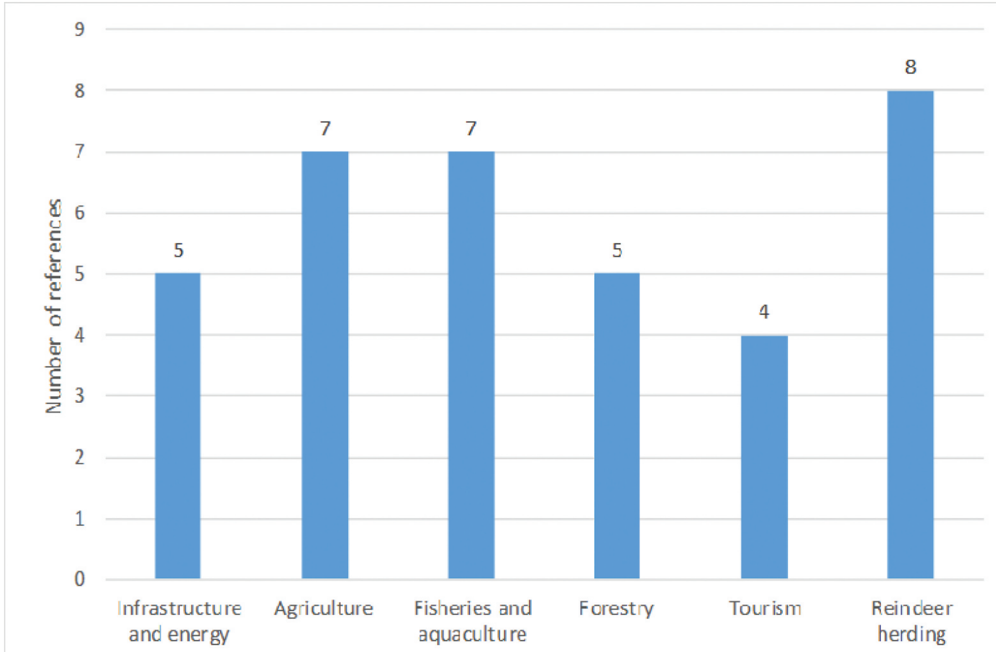
3.1. Sectoral impacts of climate change in the Barents countries

The rate of change in climate is rapid in the Arctic and affects both natural and social systems (Overland et al., 2014). In some cases, the speed of warming can exceed the rate at which different components can successfully adapt, particularly if economies are narrow and have less adaptive

Table 1. Keywords/terms used in the literature search

Common keywords used for all territories and sectors	Environmental impacts		Climate policy		Climate impacts		Climate change	Mitigation		Adaptation		
Territorial search terms	Arctic		Barents Region		Russia		Finland	Sweden		Norway	Russia	Saami
Sector-specific term	Agriculture	Infrastructure	Energy production	Electricity	Fishery	Aquaculture	Oil/gas production	Forest industry	Forestry	Reindeer hearding	Tourism	Industry

Figure 2. Number of papers selected for review per each topic.



capacity (Larsen et al., 2014). Furthermore, in many cases, the impacts of climate change will be mixed with other simultaneous changes, such as structural change in the economy and population. Thus, the economic activities in the Barents region will be affected both by mitigation and the residual climate change. Furthermore, the climate impacts are yet very uncertain, and particularly impacts after 2050 are very dependent on the level of mitigation (Overland et al., 2014). There is also strong spatial variation in the impacts of climate change in the Arctic because the communities, biophysical regions and drivers of change are different in the different regions (Eliasson et al., 2017).

Based on the TIMES-VTT modelling, statistical data collection, and the literature review conducted, an overview of these impacts was formed and it is presented in the following for the different sectors.

3.1.1. Electricity production and demand projections

The electricity production mix is notably different between Barents region countries. Norwegian and Swedish Barents regions have high amounts of hydropower while Finnish and Russian Barents have relatively more thermal capacity. Russian Barents uses notable amounts of natural gas, along with hydro and nuclear power.

According to the results of the TIMES-VTT modelling, decarbonisation of the power and heat sector is the most cost-efficient solution to reduce emissions. Electricity demand and generation increased in the RCP 2.6 scenario in all the Barents countries. In addition, the model was able to decarbonize other sectors through electrification, e.g., electric vehicles, only when the provided electricity was CO_2-free. At the same time, Nordic countries electricity surplus increases and they export more electricity to Central Europe which has relatively less renewable resources.

Residential sector did not cause large direct emissions but was indirectly responsible for a share of power and district heat emissions through to the consumed energy. The energy efficiency in buildings increases in both RCP2.6 and RCP4.5 scenarios, reducing the total energy demand of the building sector. In addition, fossil fuels in direct heating were replaced with renewable alternatives and heat pumps. Oil heating in the residential sector would end by 2030 in the RCP2.6 scenario. replaced by, e.g.,, heat pumps.

Investments in electricity transmission and demand side management will become more important when the system has higher share of variable generation (solar, wind) and variable demand of electricity increases (e.g., electric vehicles and heat pumps). The Barents region can contribute to the future energy systems with balancing the flexible production (hydro and biomass) to match demand-supply imbalances and by exporting additional electricity to Central Europe, but the economies depend on the expected costs of additional transmission capacity and market price of electricity.

Energy sources and infrastructure will also be affected by climate change. Climate change impacts are likely to vary from one energy carrier to another. Generally, renewable energy can be more vulnerable to climate change than fossil energy resources due to its dependence on weather (Schaeffer et al., 2012); but renewable energy also promotes energy security, as it is typically available on-site and is not dependent on imported fuels.

Increased precipitation will increase the availability of hydropower as well. However, flooding is also likely to increase because it is not possible to utilize all the additional precipitation in existing or potential new hydro-reservoirs (Seljom et al., 2011). According to Vormoor et al. (2015), autumn/winter floods are expected to intensify, and may also lead to a systematic shift in the current flood regimes from spring/summer to autumn/winter regime.

Climate change can have an impact on the integrity and reliability of electricity grids and pipelines. These impacts can be particularly strong in Barents and other Arctic regions because temperature increases are likely to be higher than average at the higher latitudes (Hoegh-Guldberg et al., 2018). Moreover, in the most North-Eastern parts of the Barents region, the melting of permafrost may cause destabilization of pillars or prevent access for maintenance and repair (Arent et al., 2014).

3.1.2. Oil and gas production

Currently, the volume of oil and gas production in the Barents region is modest compared to total volumes in Norway and Russia (6% and 3%, respectively), but the volume could increase significantly in the future if market conditions are favourable. The Barents Sea has vast oil and gas resources, and high hopes are often placed on the future of Barents region as a new province for global oil and gas markets (Lempinen, 2018). Existing infrastructure is limited, however, and significant investments are required for the exploitation of these resources (Norwegian Petroleum Directorate, 2016; Oxford Institute for Energy Studies, 2014).

The costs in oil and gas exploration and recovery vary between the fields, but many new fields in the Barents region can have relatively high extraction costs due to the infrastructure needs and Arctic conditions. This makes the projects in the Region more susceptible to price risks, e.g., varying price or lower price in general due to declining demand under the Paris Agreement. On the other hand, future production and transport costs in the Barents region might decrease due to lower sea ice extent and the decreasing amount of days when the sea is frozen. Based on the TIMES-VTT modelling conducted, the upstream emissions from fuel extraction, pipelines, and refining are reduced, but less than in other energy use sectors. Emissions of flaring, venting, and pipeline leakages are estimated to be easier to reduce than emissions from refineries, but there could be possibilities to replace fossil fuel feedstock with biomass or apply carbon capture and storage (CCS) to refineries.

3.1.3. Manufacturing and mining industries

The Barents region has relatively more manufacturing industry than the southern parts of the Barents countries. Notable sub-sectors include mining, pulp and paper, metals, machinery and electronics. The impacts on industry are especially important for the Barents region. The importance of the mining sector in the Barents region may increase further in the future because the Barents region has considerable potential for new mines and production of minerals.

Industrial emissions are often closely linked to the processes. Industrial processes can increase efficiency and switch fuel to some extent, but such changes might have to be linked to wider modifications in the industrial installations. The fuel switching within industry should be the easiest in industrial power and heat production, where fossil fuels could be replaced with lower emissions fossil fuels (natural gas), biomass, or electricity. All these take place in the RCP2.6 scenarios modelled but in much lower extent than in residential power and district heat production. Industrial process emissions are considerably harder to mitigate but can be reduced with fuel efficiency, recycling of steel and aluminium, replacing cement and concrete by wood in buildings, and new non-commercial technologies, such as CCS and using biomass feedstock as a carbon source. However, using biomass, as an example, in a blast furnace to replace steam coal would require such an amount of biomass that is not possible to produce sustainably.

3.1.4. Transportation

The Barents region is sparsely populated and transportation distances are long. Despite the urbanization trend, transportation is a necessity with very limited substitutes. Moreover, the Barents region has significant forest resources, which could be used as a feedstock for advanced biofuel production and export to other regions Given the long distances in the region, advanced biofuels are likely a more viable way for contributing towards mitigation and the Paris Agreement, as electric vehicles are likely to have a more limited range than internal combustion engines (Figure 4 and 3). However, whether forest-based biofuels lower the carbon-sinking capacity of the region's forests has been questioned in many studies (Kallio et al., 2013; Withers et al., 2015).

The level of additional electrification is limited by large share of heavy transport, shipping and aviation in the Barents region countries. Several companies are developing electric heavy trucks, electric airplanes and electric ships, but these are in the very early phase of the development and there was not enough information to include these into the modelling. If these technologies mature successfully, they can replace biofuels with electricity at least to a certain share.

Figure 3. Electricity generation in the Barents region countries up to 2050 in the modelled RCP 2.6 and 4.5 scenarios. Category "Other fuels" consists mostly of municipal waste.

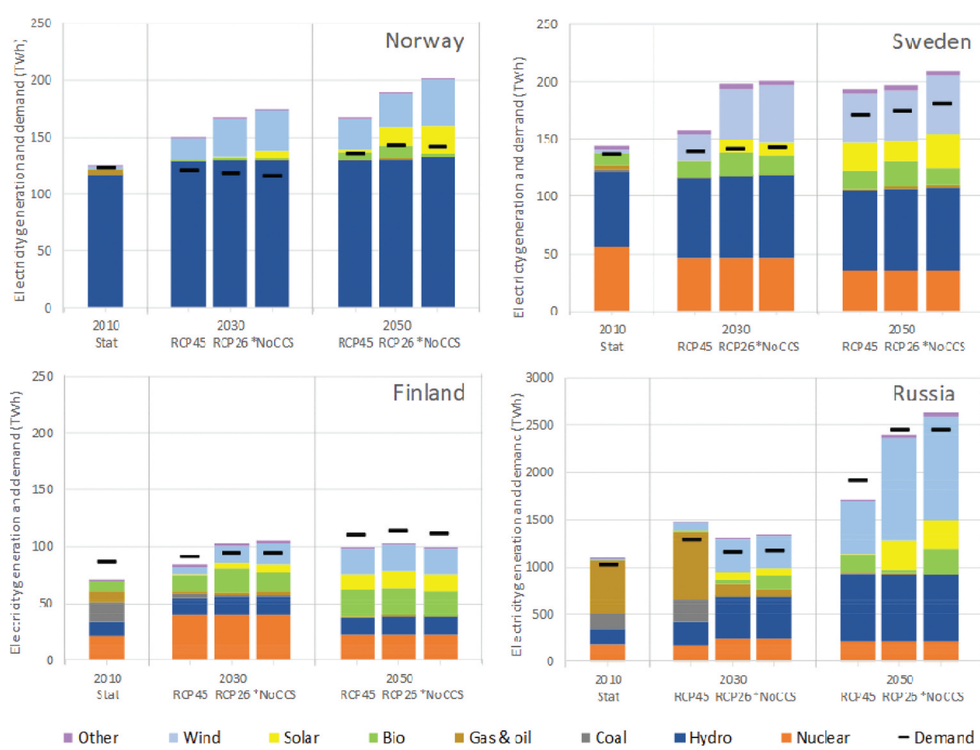


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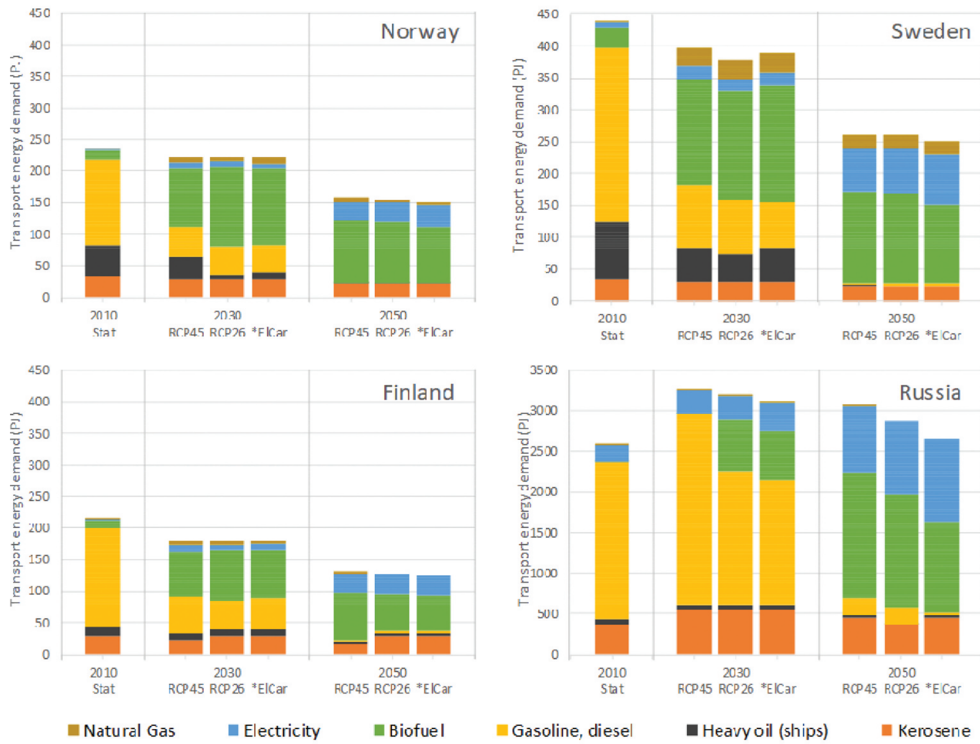
Figure 4. Modelled energy consumption of domestic and international transport in the Barents region countries up to 2050 in the RCP 2.6 scenario.



3.1.5. Agriculture

Agriculture is important for the social and economic viability of the Barents region's rural areas (Arctic Monitoring and Assessment Programme, 2017). Presently agriculture in the Barents region is based on animal breeding (cows and other ruminants) and grass farming (Hannukkala & Kietäväinen, 2017).

According to the TIMES-VTT modelling conducted, in the Barents countries as a whole, agricultural emissions remain notable up to 2050. With warming temperatures, it is likely that farming will become more important in the Barents region. According to an assessment conducted in Northern Norway, the growing season[2] will increase by 6–30 days over the period 2021–2050 (Uleberg et al., 2014). Knox et al. (2016) conclude in their systematic review on the impacts of climate change on crop yields in Northern Europe that over 10% yield increase is expected in the region by 2050s. This also implies an increased potential for exports of agriculture production to low-latitude regions where the impacts of climate change on agricultural production are expected to be severe (Knox et al., 2016). Furthermore, Höglind et al. (2013) found a potential increase in timothy yield throughout Finland, mainly as a result of increased temperatures. On the other hand, according to Peltonen-Sainio et al. (2018), the present cultivars are adapted to the short growing season and long days typical for the northern regions, and they thus lack capacity to benefit from prolonged thermal growing season. Harvests are likely to take place earlier than today and therefore the authors found yield benefit from warming springs but not from warming autumns.

Potentially positive impacts of climate change on agricultural production in Northern Europe also mean that crops that are presently marginal, or not grown at all in certain areas, could become feasible and there could therefore be potential for crop diversification (Peltonen-Sainio et al., 2018). When temperature increases, the availability of light may increasingly become the most crucial variable for plant growth (Uleberg et al., 2014). Limited light availability limits the potential to lengthen the growing season in the autumn and earlier onset of spring may therefore become the critical factor for agricultural production. In order to begin farming earlier, the ground needs to be dry enough. If it is too wet, ploughing is not possible. Plant breeding can have an important role in the adaptation of agricultural production to the changing winters, longer autumns and varying conditions during the growing season. One option to benefit from the warming autumns and modify the risks of increased autumn precipitation could be the use of cover crops. Nutrient scavenging catch crops can be used to provide the needed soil cover and thereby protect soil from erosion and compaction, produce biomass in the following season, and increase soil carbon storage (Peltonen-Sainio et al., 2018).

On the other hand, warming also makes conditions more favourable for plant diseases and weeds (Peltonen-Sainio et al., 2018). A crucial process for plant survival over winter is cold-hardening during autumn. Warmer autumn days may shorten the winter hardening period by even a few weeks, making the plants less hardened (Peltonen-Sainio et al., 2018).

Climate change can also have impacts on animal husbandry. Increased afforestation or bush formation on pastures decreases pasture quality, which reduces sheep body mass (Dannevig et al., 2015). Precipitation and temperature increase may result in foot rot and appearance of new diseases. On the positive side, an increased growing season can contribute to higher lamb weight and increased animal numbers (Dannevig et al., 2015). Furthermore, for animals that are kept indoors in the winter, shorter and warmer winters reduce the need for shelter and feed concentrates (Uleberg et al., 2014).

3.1.6. Forestry

Forestry is presently practiced in the southern part of the Barents region, and it has an important role in the Swedish, Finnish and Northwest Russian Barents (Arctic Monitoring and Assessment Programme, 2017). Forests have a key role particularly in the climate and energy policies of Sweden and Finland. The productivity of the forests in the boreal areas is usually limited by short growing season, low summer temperatures and shortage of nitrogen (Kellomäki et al., 1997; Ohse et al., 2012). Warming temperatures may have a positive impact on forests as forest growth may increase and forests may spread further north to areas which are presently treeless. If the global average temperature increases by two degrees, the growing season can increase by 1–2 months in Sweden (Eriksson et al., 2016). The predicted increase in temperature would prolong the growing season and enhance decomposition of soil organic matter and availability of nitrogen (Lindner et al., 2010). Yet, it should be noted that the forest growth models usually do not take into account possible increases in diseases or insect damage. Furthermore, the changes in climate are fast in relation to the capacity for natural adaptation of trees and other species.

Eriksson et al. (2016) estimate that in the Nordic countries under RCP4.5 scenario, rainfall will increase by 15–20% over this century. However, there are uncertainties over the exact impact of climate change, which can be negative as well, e.g., through increased rainfall which could aggravate the conditions for wood harvesting, and through increased storm damages (Eriksson et al., 2016). In addition, variations in temperature during winter may worsen conditions for seedlings and endanger their survival over the winter (Rautio, 2017). This has considerable impacts on costs as well because re-establishing the forest is the most important phase in forestry. Changing climate and snow-fall are also likely to have an impact on forestry through potential changes in snow-induced damage. Kilpeläinen et al. (2010) and Lehtonen et al. (2016) have both studied the impacts of climate change on snow-induced damage on forests in Finland. While Kilpeläinen et al. (2010) found the risk of snow damage to decrease throughout the country also in Northern Finland (Lapland), the results by Lehtonen et al. (2016) indicate the opposite. According to their study, the maximum snow loads are likely to grow in Northern and Eastern Finland when climate gets warmer, implying an increasing risk for snow damage (Lehtonen et al., 2016).

Boreal forest fires presently mainly take place in Siberia, Alaska and Canada (Flannigan et al., 2009). Climate change is likely to increase the severity and frequency of forest fires, but in the Barents region, this primarily concerns the Russian Barents. According to the European Environment Agency (2017), none or only small increase in forest fire incidence is expected in the Nordic countries.

3.1.7. Fisheries and aquaculture

Global supply of fish for human consumption has grown faster than human population over the past 50 years, increasing per capita consumption from 9.9 kg in the 1960s to the present level of approximately 20 kg per capita (FAO, 2016). For millennia, fishing was almost completely based on capturing of wild fish but over the past decades, the share of aquaculture has been constantly growing, being over 40% of the total fish catch at the moment. The greenhouse gas emissions of fisheries mainly stem from N_2O emissions. N_2O emissions from fish farming were about 93 kt N_2O-N in 2009, which represents less than 2% of the global total agricultural N_2O-N emissions (Reay et al., 2012; Smith et al., 2014).

Climate change has major impacts, both positive and negative, on the future of the fisheries, including fishery-related activities and supporting industries. In a global assessment conducted by Handisyde et al. (2017), Norwegian aquaculture (together with that of Chile) was found to be the most vulnerable to impacts of climate change. In the Barents Sea, temperatures are likely to increase by 2–10 degrees due to climate change, sea ice will be significantly reduced or even disappear completely, and salinities are likely to decline due to increased precipitation and higher fresh water run-off from rivers by 2100 (Filin et al., 2015).

Warmer temperatures and reductions in sea ice can lead to higher phytoplankton production, which in turn is likely to result in higher fish production (Haug et al., 2017). In addition to cod, which seems to be the most studied in the Barents Sea, other species are likely to be markedly impacted as well (Filin et al., 2015). Herring, blue whiting and eventually Atlantic mackerel are expected to expand eastwards. This could potentially reduce cod populations but studies also indicate that cod populations will grow as a result of warming (Haug et al., 2017; Kjesbu et al., 2014). Moreover, climate change is likely to result in overall higher production, and thereby larger catches of haddock, herring and other boreal species (Filin et al., 2015).

The recent warming in the Barents Sea has already led to changes in the spatial distribution of the fish communities (Fossheim et al., 2015; Wiedmann et al., 2014). Boreal fish communities, particularly large, migratory fish predators, have expanded northwards, especially in the summer period (Haug et al., 2017).

For the fishing industry, changes in the distribution of fish species can mean changes in the operation time and distance for the fishing vessels. Moreover, higher prices for carbon might increase operation costs. On the other hand, climate change can also have positive impacts on aquaculture. In their study on the impact of temperature increase on salmonid farming in different Norwegian regions, Hermansen and Heen (2012) found that the impact of warming on salmonids is generally very positive in Northern Norway if relocation of production is allowed freely. Production units are likely to move away from Northernmost and Southernmost regions. In Northern Norway, Nordland county would considerably benefit while Finnmark and Troms would lose some production units. Tiller and Richards (2018) studied the views of stakeholders from commercial fisheries and aquaculture in Northern Norway. According to their assessment, the representatives of fisheries were not worried about the relocation of fish populations per se (the replacement of saithe by mackerel, which they are already observing) but of the fact that they did not have access to a quota for catching the mackerel. The main concern of the aquaculture was to have access to flexible and accessible areas in the future with the climate changing (Tiller & Richards, 2018). There are anticipations that a manifold increase in the production volumes in the Northern Norway is needed in the future in order to replace the reduced production in the southern Norway due to warming waters (Tiller & Richards, 2018).

However, as there are large uncertainties concerning the impact of climate change on the Barents Sea, and as also factors other than temperature affect the ocean, such as changes in fishing intensity, time and place, and acidification due to increased carbon dioxide concentration in the air, improved management has been implemented since 2003 and robust management strategies will continue to be needed in the future as well (Filin al. 2015; Handisyde et al., 2017).

3.1.8. Reindeer herding

Reindeer herding has been practiced across the Arctic countries, including the Barents region for thousands of years. Reindeer herding is a fairly small-scale activity in the Barents region. It is important locally, though, and in some areas, it is a significant employer, such as in northern Finland where there were 4421 owners of reindeers, and reindeer herding was a significant source of income for 1000 households in 2016 (Ministry of Agriculture and Forestry, 2017). In Northern Finland, Sweden and Norway, reindeer herders have good access to markets and there is a lot of consumer demand for reindeer products. Also in parts of the Yamal Peninsula and the Nenets Autonomous Okrug, the oil and gas booms of the recent years have had a positive impact on the income level of reindeer herders.[3] However, in many Russian reindeer herding areas, herders are having problems because of the poor state of the local economy, and herders' lack of access to the markets.

Generally, it has been estimated that the impact of reindeer herding on climate change is minimal. However, climate change may impact reindeer herding particularly through changes in the availability of fodder. These impacts are likely to vary from region to region. Climate change is anticipated to result in greater variability in temperatures, weather, snow melt and freeze, ice, winds and precipitation, and this is likely to impact the reindeer herding communities, e.g.,, through snow quality and quantity, which are critical for the sustainability of reindeer herding (Larsen et al., 2014; Mallory & Boyce, 2018). For example, ice layers over the snow would block reindeer access to forage and result in starvation unless the animals are not given supplemental food. On the other hand, later snowfall or earlier snowmelt benefit reindeer as they have easier access to forage (Kaján, 2014). Shorter winters can thus also mean reduced starvation and mortality of animals (Dannevig et al., 2015).

Moreover, increased bush and tree-growth have already been observed by reindeer herders and the trend is expected to become stronger. Research indicates that reindeer herding could potentially also contribute to a cooling effect, at least on those limited areas that have high reindeer densities, as grazing decreases the growth of the shrubs and thereby increases albedo (Te Beest et al., 2016). Vowles et al. (2017) conclude that the impact on reindeer and other herbivores is determined by how they influence the competitive balance of plant species, and may thus be very site-specific.

As reindeer herding has and continues to be affected by other societal processes as well, such as habitat fragmentation and land use changes, these together with climate change impacts can lead to cumulative effects (Markkula et al., 2019). If reindeer pastures become fragmented due to, for example, infrastructure development, there is less land available to substitute areas that have become unusable due to climate change, and reindeer herders' cooperatives face increased costs as a result of adaptation actions (e.g., helicopter surveillance or transportation of animals to new areas). Furthermore, increased costs may be caused by delayed winters requiring terrestrial vehicles in collecting and moving herds (Turunen et al., 2016).

3.1.9. Tourism

Globally, it has been estimated that tourism is responsible for about 5% of the global CO_2 emissions (UNWTO, 2018). Emissions related to tourism mainly stem from the transportation and accommodation.

Tourism has been identified as one of the main drivers of economic growth in the Scandinavian Arctic in the Barents region (Arctic Monitoring and Assessment Programme, 2017; Prime Minister's Office, 2015). Its growth is expected to continue but there is likely to be an increasing emphasis on large cruise ships and land-based winter and summer tourism (Arctic Monitoring and Assessment Programme, 2017).

Tourism in the Barents region is mainly based on nature and natural resources, for example, fishing. Tourism is therefore also particularly vulnerable to the impacts of climate change, especially those communities whose economies rely mainly on tourism (Kaján, 2014; Nicholls & Amelung, 2015). The impacts of climate change on tourism can be both negative and positive. Negative impacts include increases in temperature variation and unpredictability, which makes planning more difficult (Førland et al., 2013). Earlier snow melt can shorten the season and therefore mean less income. Moreover, increased temperature variation and the resulting unpredictability in snow and ice conditions could bring about safety issues (Kaján, 2014). Several adaptation measures to cope with the warmer temperatures have already been used, including snow-making, shading and wind sheltering among others (Demiroglu et al., 2018).

On the other hand, in the coastal areas of Northern Norway, for which tourism is one of the primary sources of income, temperature has always been variable. Førland et al. (2013), compared preferences of international visitors in Norway during summer to predicted changes in temperature, precipitation and cloudiness. They found that tourists do have a preference for an increased number of warmer days. They are fine with some increase in rainfall but recurrent precipitation is disliked by most of the visitors. Furthermore, such consequences of climate change as migration of the tree line, taller bushes and changes in the species composition have an impact on tourism. In a workshop held by Tiller and Richards (2018), stakeholders representing the tourism sector in Tromssa indicated that they were dependent on the Northern lights. This is worrying as according to most projections, precipitation levels in the high latitudes in Northern Europe are projected to increase (Hoegh-Guldberg et al., 2018), which implies more cloudiness and thereby reduced northern lights.

Positive impacts of climate change include reduction in temperature extremes (less extreme colds), which is beneficial for outdoor activities in the winter. Førland et al. (2013) point out that in the longer-term managers of the tourism sector should pay attention to marketing the "improved" weather conditions as many tourists have an overly negative picture of the climate. Earlier snow melt implies a longer summer season, which in some regions may bring in more tourists but in others that are more concentrated on winter tourism, may shorten the term. For alpine sports, a shorter winter season can also mean that more artificial snow has to be produced, which increases costs and energy consumption of the activity.

4. Conclusions

The rate of change in climate is rapid in the Arctic, and it is affecting both natural and social systems. In this study, we have studied the possible impacts to the economy that can arise from climate change and its mitigation. The results show that the impacts are manifold, ranging from positive to negative, and being different from one sector to another. The positive impacts include increased energy security through higher reliance on renewable energy sources, and the potential agricultural benefits from higher yields and the introduction of new crop species to areas that were previously too cold for them (Knox et al., 2016; Peltonen-Sainio et al., 2018).

While there are potentially positive impacts of climate change on economic activities in the Arctic, there are also a lot of possible negative impacts. These include, for example, the economic costs and risks due to potential damage from ice and flooding to installations such as bridges, pipelines, drilling platforms and hydropower (Arent et al., 2014), increased occurrence of plant diseases and weeds due to warmer temperatures (Peltonen-Sainio et al., 2018) and higher prevalence of snow and storm damages on forests (Eriksson et al., 2016; Lehtonen et al., 2016).

The impacts of climate change will thus create both pressure for businesses to adapt to changing conditions, but also offer several new opportunities. While the economy is faced with a need for industrial renewal, the markets are growing for renewable energy and clean technologies, including energy- and material-efficient machinery and appliances. This can be an opportunity the Barents region can grasp, should an appropriate understanding of the future development trends and the ability to enter the markets be in place. On the other hand, when climate change weakens the potential of local people to live on traditional livelihoods, they become increasingly dependent on global economy, and thereby more vulnerable (Raheem, 2018). For example, warming affects travelling on sea ice, which can compromise food security by reducing possibilities for hunting (Raheem, 2018). This particularly applies to situations where the local economies are narrow and therefore have less adaptive solutions available, such as in communities relying on the informal, subsistence-based economy (Larsen et al., 2014).

Climate change mitigation and adaptation are continuous processes. It is crucial to observe the actual development, learn from it, and update the targets and measures when necessary. It will be essential to find a healthy balance between solid long-term targets, new prospects of developing technology, and new scientific information. Even the ambitious RCP 2.6 scenario has significant climate change impacts already by 2050, but especially by 2100. Management strategies that consider both mitigation requirements and the impacts of climate change as broadly as possible can be recommended. For example, in order to prepare for increased rainfall in the summer, tourism managers should develop activities that are weather independent (Førland et al., 2013). Furthermore, infrastructure and financial capital are crucial in adapting to the impacts of climate change. The availability of electricity, sewage systems, health and education services and regional communication centres, among other factors, provide the basis for successful adaptation (Dannevig et al., 2015). Potential impacts of climate change should always be considered in spatial planning and when building new infrastructure.

In the Barents region, it is important to highlight and suggest priority areas to national adaptation plans from the region's perspective. Indigenous and other local knowledge should be collected and utilized in the adaptation. It is essential that there exists necessary support mechanism for local communities including indigenous communities, in agriculture, aquaculture, and reindeer herding to adapt to the impacts of the climate change. Municipal authorities should reflect estimated impacts and adaptation needs in the zoning, planning, and other future strategies.

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Notes
1. https://www.barentscooperation.org/en
2. A growing season means the time period when the weather allows plants to grow. Different regions and different plants have different growing seasons.
3. http://reindeerherding.org/challenges/economy/

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